FIRE SCIENCE ADAPTATIONS FOR THE SOUTHEASTERN U.S.--A RESEARCH UPDATE 1980-1984

DALE D. WADE[1]

Abstract.--Fire Science Research Work Unit accomplishments 1980-1984 are summarized and publications listed. Current fire behavior and fire effects investigations are briefly described.

INTRODUCTION

One of the most important resource management challenges facing the South is to provide a greater share of the Nation's wood fiber from a shrinking forest land base (e.g. see Barras 1984). The intentional use of fire not only can, but must play a greatly expanded role if this challenge is to be met.

During an average year, slightly more than 50 percent of the Nation's wildfire acreage is in the 13 Southern States. An alarming proportion of this acreage occurs in young pine plantations where damage is often severe. The magnitude of these losses is much greater than generally realized. For example, during the 1976 fire season, close to 30,000 acres of pine, with an average age of 6 years, were blackened (Wilson 1977). And during the first 10 months of 1981 an estimated 75,000 acres of 1-10 year old pine plantations were burned in the 13 Southern States (U.S.D.A. Forest Service 1982). Protection of the roughly 19 million acres in pine plantations and the 42 million acres of natural pine in this region should thus be a top priority.

How Can Prescribed Fire Help?

Prescribed fire is the only practical way to reduce the fuel hazard in established pine stands, but less than 4 million of the 61 million acres are intentionally burned each year. Moreover, fire is seldom prescribed in young pine stands where the damage potential from wildfire is greatest.

Prescribed fire can also increase tree growth rates by controlling understory vegetation, especially in young pine stands. In the South, prescribed fire has been used for over three centuries to control undesirable vegetation. A major advantage of it over other alternatives is that, depending upon timing and firing technique, many plant species can be controlled rather than eradicated. Fire enhances diversity by increasing legumes and other plants eaten by wildlife such as quail and turkey. Succulent sprout growth is also promoted and the plants are kept within reach of browsers such as deer.

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[1] Acting Project Leader RWU SE-2111

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A third major area where prescribed fire increases productivity is in preparing sites prior to planting pine, which is an almost mandatory practice in the South to set back hardwoods that compete with the pine seedlings. This need is especially great on the more marginal sites that continue to be put into timber production (Guldin 1984). Currently fire, machines, chemicals, or some combination of these methods are used, but, if the costs of diesel fuel and heavy equipment continue to escalate and herbicide restrictions continue to tighten, fewer acres will be treated with chemicals and heavy equipment. Thus, if productivity is to be increased, the use of low cost, efficient alternatives such as prescribed fire will also have to increase.

CURRENT RESEARCH

The research mission of Research Work Unit-2111 in 1980-1984 has been to develop, adapt and incorporate into cost effective methods the fire science information necessary to expand the use of prescribed fire in southern forests. On holdings where prescription fire is routinely used, we are developing the information that will enable a substantial increase in the area that can be safely treated on the few ideal burning days that occur each winter as well as developing the data base necessary to widen the prescribed burning window.

On forest land currently being managed without the benefits of prescribed fire, our goal is to better quantify the behavior and effects of fire, and demonstrate its predictability.

Research to accomplish these objectives is grouped into three broad areas:

1. The evaluation of spot firing techniques
2. The development of methods for predicting fire behavior and effects
3. The quantification of the effects of fire on vegetation

Ongoing research in each of these areas will be briefly described.

Evaluation of Firing Techniques

This broad topic area has been divided into (1) assessment of aerial ignition guidelines and (2) comparison of the behavior of spot-and line-ignited fires.

Aerial ignition guidelines.--Using conventional ground ignition methods, resource managers rarely have enough good burning days during a given year to treat the acreage scheduled. As the number of possible days remaining decreases, managers often attempt to use marginal weather conditions, with results ranging from a simple decrease in benefits to an unacceptable increase in deleterious side effects. The temptation to use marginal burning conditions could be virtually eliminated by the development of dependable, cost-effective aerial ignition techniques. Aerial ignition has numerous advantages over ground ignition, but perhaps the most important is the enormous increase in acreage that can be treated during a given burning period. Increases in safety and efficiency, and the potential for a substantial reduction in overall cost make aerial ignition all the more attractive.

Both the aerial ignition device (A.I.D. or "ping-pong ball") system and helitorch or "flying drip torch" system can be used to ignite spot fires. Individual spots simultaneously head, flank, and back as they grow and eventually burn into each other. We have developed preliminary criteria for spacing igniters in southeastern fuel types (Johansen 1984a, 1984b) and evaluated different helitorch equipment configurations (Johansen [In press]). Previous work (Sackett 1968) showed a direct correlation between the number of ignition points per acre and the amount of crown scorch, but under the spot fire ignition grids (1 ch. x 1 ch. to 4 ch. x 4 ch.) and burning conditions used in our present studies, we found spacing had little effect on scorch height. The operational ramification of these results is to use the 4 ch. x 4 ch. ignition grid because it requires less flying time and fewer ignitions. In our studies, undesirable flame heights and attendant crown scorch were associated with spot fire merger, particularly on rectangular grids where the flanks of spot fires along a given ignition line tended to come together before the heads ran into the backfires from the next downwind line of spots.

Differences in burning conditions may account for the contrast between our results and those of earlier studies. Most of our fires took place at the "high" end of the prescribed burn scale. The forward rate of spread of the individual spots increased from 8'/min. in the 1 ch. x 1 ch. spacing tests to 14'/min. in the x 4 ch. x 4 ch. spacing indicating that intensity continued to increase as the spots spread. Thus the increased intensity of the individual spots at the wide spacings compensated for the reduced merge line distances resulting in about the same degree of scorch regardless of spacing.

We cannot tell from these study results what the effects of ignition grids wider than 4 ch. x 4 ch. would be or what the effect of different fuel moisture and weather conditions on spot fire behavior would be.

Because our suggested 4 ch. x 4 ch. grid which results in only 1 ignition per 1.6 acres and because the sphere of influence of each igniter is only slightly larger than a ping-pong ball, this system is best for continuous fuels. The flying drip torch emits a steady stream of burning fuel globs which provide many more potential ignitions per unit of line flown. This system thus works well in discontinuous fuels such as are found in many clearcuts. When the flying drip torch is used in continuous fuels, the many ignitions per unit of flight line rapidly establish a line of headfire with its associated higher intensities and potential for higher scorch than does the ping-pong ball system under the same conditions.

Spot vs line fire behavior.--Although early controlled burns were spot fires, they were replaced by line fires with the introduction of the drip torch. The behavior of spot fires therefore has been virtually ignored except in the unique ecosystems of South Florida where Everglades National Park in cooperation with the Southern Forest Fire Laboratory pioneered the use of aerial ignition in the South. (Sackett 1975; Wade, Ewel & Hofstetter 1980).

The behavior of spot fires under various weather and fuel conditions must be determined before guidelines relating ignition point density to fire parameters such as intensity and burn-out time can be established. Information on fuel consumption and emission rates is also needed to calculate air-quality impacts. In my judgment, the use of weather conditions normally considered ideal for line-ignited backfires is the major reason some aerially ignited burns have produced intensities above those called for in the prescription.

With spot firing, most of the area is burned by headfires, which spread faster and are more intense than line ignited-backfires, although they are not as fast, or as intense as line headfires.

Spot fires don't have to be ignited from the air to be effective. For example, the Oconee National Forest has implemented a burning program in Piedmont fuel types using strip headfires. This firing technique necessitates a halt in ignition whenever conditions get too severe--as often occurs during the heat of the afternoon. Ignition can generally be resumed in the evening but this is outside normal work hours and smoke dispersion is generally poorer at night. Backfires aren't practical because of the lack of interior plow lines. Consultation with our Research Work Unit resulted in a novel solution; now whenever line headfire behavior becomes too intense,the firing crew simply switches to spot fires. Torch people walk the same distance but instead of stringing a line of fire, each ignites a spot every so many paces. This technique also allows more area to be ignited between torch refills.

Future work.--Because aerial ignition is rapidly replacing line firing on many agency and industrial land holdings in the South, operational guidelines are urgently needed. Moreover, many managers still have a nagging fear regarding damage that might occur from having too many spot fires burning on a given area at the same time. I believe the greatest potential of aerial ignition is on the damper end of the prescribed burning window, where individual spots will not merge into an uncontrollable inferno. But, if this phenomenon is to be avoided, threshold conditions for its development should be established.

Methods For Predicting Fire Behavior and Effects

If the South is to meet its wood fiber production goals, better protection and increased growth rates of existing stands will be mandatory, and the judicious use of prescribed fire is perhaps the most economical means of accomplishing these tasks. But how can this tool be sold to the managers of the tens of millions of acres where it is not currently used? The reasons for not using fire where it has obvious potential are varied and include misconceptions or ignorance regarding the benefits of prescribed fire. However, I believe a major reason is simply that these landowners attach a subjectively high probability to the potential for resource damage and litigation. While qualitative guides (e.g. Mobley et.al. 1978) have sufficed for those now using prescription fire, we need site-specific predictors of fire behavior and effects that work under a wide range of fuel and weather conditions in order to expand the window of opportunity for prescription burning. Researchers have attempted to devise fire damage prediction systems based on measures of fire intensity for over 50 years, but solutions have proved elusive. One stumbling block has been the lack of a good method for rating the behavior and effects of prescribed fire. There would be numerous advantages to adapting an existing, commonly used, fire intensity predictor such as flame length.

Flame length-- The use of flame length as an indicator of fire behavior has received wide acclaim since Byram (1959) published an equation relating flame length to fireline intensity. The concept is appealing, but length has proved to be exceedingly difficult to measure accurately. Johnson (1982a) found that actual flame length measurements did not agree with predicted values based on existing equations that express the relationship between fire intensity and flame length. More recent work, however, suggests that flame lengths were simply not measured accurately enough.[2]

Fuel weight.--Fuel consumption is another fire behavior descriptor. This parameter is dependent upon total fuel which is itself usually predicted. Generalized prediction equations for southern fuel complexes exist, but there is much room for improvement.

We are using our archived forest floor fuel data to develop more accurate litter weight accumulation prediction models for loblolly, longleaf and slash pine based on age of rough and stand basal area. Information regarding shortleaf pine has already been published (Johansen, Lavdas & Loomis 1981). These estimates are used to calculate fuel consumption which is a cornerstone of most fire intensity, fire effects and smoke management models.

Moisture content.--Live and dead fuel moisture are also major determinants of fire behavior. Yet their accurate prediction remains a goal in the South. Eventually the National Fire Danger Rating System (NFDRS) or Canadian Fire Weather Index (CFWI) equations should probably be adjusted to better reflect southern conditions. In the meantime, we have lent a degree of scientific backing to the time-honored "crackle test"[3] used by most southern woods burners (Johnson 1984a).A study is currently underway to assess the foliar moisture response of selected understory species on the Georgia Coastal Plain and Piedmont to changes in soil moisture as measured by four commonly used drought indices, the objective being to relate changes in flammability to changes in these indices. Results of this study have been accepted for presentation at the Eighth National Conference on Fire and Forest Meteorology scheduled for April 1985 in Detroit.

National Fire Danger Rating System.--Several components and indices of the NFDRS, which most federal land management agencies are required to use, are designed to estimate the behavior of an initiating fire under given fuel and weather conditions. But most of these predictors are "notoriously unreliable throughout much of the southeast region" (Johnson 1980).[4] We attempted to evaluate NFDRS models C, O, and P by comparing predicted fire behavior with observed data on archived fire reports. We hoped for a fair degree of correlation, but none was found. Our cooperator (Williams 1983) gave two reasons. First, he found a surprising number of errors at all levels of input which he did not think were due to a lack of exposure to training. Rather, he blamed the observers preconceived notions that the NFDRS was not worth using. The second finding, which could not be conclusively shown in light of the first was that the various indices and components needed to be normalized for southern conditions.

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[2] Data on file at Southern Forest Fire Laboratory.

[3] The estimation of fuel flammability by picking up a few upper litter layer needles or leaves and subjectively determining their tendency to snap or bend.

[4] Fire science adaptations for Southern United States. Res. Work Unit Description (SE-2111), 6p. On file, South. For. Fire Lab., Dry Branch, GA.

Future work.--If the NFDRS is to give meaningful results in the South, its indices and components will need to be adjusted for southern conditions because fire danger-fire behavior response curves do not agree with predicted values. Some, but certainly not all, of the NFDRS shortcomings can be corrected for in the BEHAVE system. For example, the live fuel moisture damping coefficient in this system does not fit southern conditions, nor does the systems response to passage of a cold front accompanied by significant rainfall. Regardless of the shortcomings of NFDRS components and indices, the possibility that they may nonetheless provide an acceptable analog of resource damage levels should be examined.

Another priority need is to field test and adjust Van Wagner's scorch equation (Van Wagner 1973) to fit southern conditions or develop a new model as necessary.

Effects Of Fire On Vegetation

Research under this general area is divided into site preparation, productivity or species composition.

Site preparation.--The use of fire in site preparation has received increasing attention during the last several years because of herbicide restrictions and mechanical treatment cost increases. Much of this attention has focused on smoke management; our RWU investigations in this area have been in response to user requests.

One cooperative study looked at burning rate and smoke production as a function of pile configuration. Following logging, many companies pile the remaining debris in windrows for disposal using fire. These windrows take many hours to burn and produce copious amounts of smoke that follow local nighttime air drainage patterns, often resulting in pockets of severely reduced visibility. Our field experiments showed that circular piles of logging debris burned much faster and produced smoke for a substantially shorter period than did windrowed slash (Johansen 1981).

Another cooperative study with industry assessed the value of very low intensity prescarification burns upon understory recovery and pine seedling survival and growth. Frequent summer showers can force postponement of these broadcast burns for weeks at a time, causing delays in subsequent tasks such as chopping and bedding and sometimes in the planting operation itself. Cognizant of the cost of these delays, forest managers often seize the first marginal burning day, accepting a patchy burn with little fuel consumption. Results from our investigations showed that after 6 years, these low-intensity fires had no significant effects on pine survival, growth, or overtopping (Wade and Wilhite 1981).

Organic soils occupy several million acres in Florida and coastal North Carolina. Surface fires such as site preparation burns can ignite this soil. Because of the tenacity of these fires, control is exceedingly time consuming so that emissions from these fires might impact an area for several weeks. Combustion products from these slow-moving, smoldering fires differ from those produced by flaming combustion. Futhermore, the high particulate emissions from these fires often combine with high nighttime humidities to form dense fog. The Southern Forest Fire Laboratory, in conjuction with the Florida Division of Forestry described the combustion characteristics and emissions from burning organic soils as a first step in addressing these problems (McMahon, Wade and Tsoukalas 1980).

Productivity.--We have several ongoing studies designed to assess southern pine survival and growth following various levels of fire damage. The University of Florida has a cooperative study with us to look at needle moisture stress as a method of determining growth stress and to quantify the effects of growing space on tree recovery associated with various levels of crown scorch. Results are due this coming spring.

Results of a cooperative study with the Georgia Forestry Commission show a drastic immediate reduction in growth on trees with crown scorch approaching 100 percent. In fact, many of the 25-year-old trees put on virtually no radial spring or summer growth at breast height the year after this dormant season fire (Johansen 1984c). Besides the obvious economic ramifications of these results, they suggest other recently published findings (Waldrop and Van Lear 1984) showing no growth loss associated with high scorch,as determined by increment core analysis, failed to consider the possibility of missing rings.

Survival and growth of young loblolly pine plantations (1 to 8 years old) following dormant and early growing-season wildfires is being followed through a cooperative study with the South Carolina Commission of Forestry. Preliminary results have been accepted for presentation at the Eighth National Conference on Fire and Forest Meteorology scheduled for April 1985 in Detroit.

Results of the above three studies have several immediate uses. First, damage is quantified so its effects can be projected through to plantation harvest, allowing an economic analysis of replanting versus keeping the survivors. Second, the cost effectiveness of fire suppression expenditures can be addressed. These calculations can be used by fire control agencies to justify budget requests and as a basis for analyzing contemplated changes in current suppression tactics.

Fire, however, is not universally detrimental to productivity. Studies have documented growth increases associated with nutrient cycling and understory competition control. These increases should be most noticeable in young pine stands. Although these stands are the most difficult to burn safely, the potential for a well-timed fire to reduce the fuel hazard while at the same time stimulating crop tree growth is appealing. Prescribed fire is not currently used in young plantations, however, because adequate guidelines do not exist. Young stands that have come through wildfire unharmed are occasionally found though, so we know it can happen. Another cooperative agreement with the Georgia Forestry Commission is aimed at establishing damage in young pine plantations associated with an array of prescribed burning conditions. One spin-off from our South Carolina wildfire damage study of value in this area is the cataloging of burning conditions on wildfires that did not cause excessive damage. There data may lead to prescription burn criteria for young stands.

Along this same vein, a cooperative study with Georgia Kraft is charting the understory recovery and pine growth after prescribed fires of two intensity levels applied to a 5-year-old loblolly pine stand on the Georgia Piedmont.

Community composition.--Students of fire ecology are well aware of the striking differences in plant and animal species composition associated with different levels of fire exclusion, but these differences have yet to be quantified in most cases. Our long-term winter burning plots in the palmetto-gallberry and mixed hardwood-shrub fuel types of the Atlantic Coastal Plain have recently been sampled to assess differences in terms of fuel management and plant succession after 24 years under selected burning cycles. We also have a cooperative agreement with Clemson University and the Forest Science Laboratory at Charleston, SC, to analyze the results of 35 years of burning the Santee fire plots in the mixed hardwood-shrub fuel type.

Although most of the above-mentioned studies have primarily benefited timber management, we have undertaken several studies that address the benefits of fire in managing other wild-land resource values. Three such cooperative studies are described below. The first, with the Piedmont National Wildlife Refuge, is set up to compare long-term species changes in composition associated with over 40 years of fire exclusion to those resulting from a 4-year prescribed fire cycle from a wildlife habitat standpoint. The second, with Clemson University, is designed to document the short-term effects of low-intensity fire on hardwood stem quality and on small mammal habitat in the Southern Appalachians. Another multifaceted cooperative study currently being prepared for publication demonstrated the ability of well-timed fires in *Spartina* marsh to temporarily halt shrub encroachment, to favor perpetuation of the target plant species, and to improve habitat for desired wildlife species, while simultaneously enhancing conditions for increased productivity of the aquatic food chain.

Miscellaneous Studies

Several studies were undertaken in response to daylighted user needs that do not neatly fit into the above categories.

South Florida's rapidly expanding population is concentrated on a narrow band along the coast, while the virtually uninhabited interior is comprised largely of a vast marsh (The Everglades) and swamp (Big Cypress). A large percentage of the human population is retired. Many of these people have respiratory ailments, while the ever-present tourists simply desire clear skies and sunshine. Extensive fires in the interior often coincide with periods of reduced visibility from haze along the southeast coast. Wade (1980) described an unsuccessful attempt to correlate high air-pollution days along this coast with fire activity in the interior.

A similar study was conducted on the 400,000-acre Okefenokee National Wildlife Refuge in extreme southeast Georgia. Johansen and Phernetton (1982) described the effectiveness of smoke management planning for prescription burns on the refuge in minimizing potential downwind smoke problems.

Most Southern States do not have a system for reporting prescribed burning activity within their boundaries, and those that do recognize the potential errors in the acreage figures collected. In an attempt to get a better estimate of the acreage prescribed burned by large landholders and the reasons for burning, Johansen and McNab (1982) surveyed selected large landholders in 11 Southern States. They concluded that over 2 million acres were prescribed burned by large landholders in 1975, of which over 500,000 acres were treated for site preparation.

The potential of prescribed fire to manage the hardwood forests of the Piedmont and Southern Appalachians is receiving renewed attention. Johnson (1982b) briefly reviewed the effects of fire in eastern broadleaf forests, and a cooperative agreement with Clemson (Van Lear and Johnson 1983) not only provided a review of fire effects, but also identified areas where additional research was needed.

DISCUSSION

The information gained from these studies is forming the database needed to answer such far-reaching fire management questions as: How can prescribed fire costs be minimized while safely maximizing desired benefits? What are the economic tradeoffs between slow-moving backfires with little tree damage and faster moving headfires with more tree damage? What are the economic tradeoffs between interior plow lines and longer burn-out times? How much damage can be tolerated in young pine stands from hazard reduction burns?

Another end product of our research efforts will be a series of state-of-the-art publications outlining the role of fire in various southern ecosystems. Slash pine (Wade 1983), melaleuca (Wade 1981), and 10 South Florida ecosystems (Wade, Ewel and Hofstetter 1980) have already been addressed, while Johnson (1984b) covered the practice of prescribed burning itself.

SUMMARY

The 27 research studies and the 21 publications to date accomplished under the auspices of the Fire Science RWU during its current 5-year charter represent a balanced attack on some of the more important unknowns associated with fire in the Southern United States.

With your continued help in research planning and study execution, the next 5 years will be even more productive.

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